Refuge Unit: Kenai National Wildlife Refuge
Reporting Office: Kenai National Wildlife Refuge
Protocol Number:
Resource: Fuel loading and vegetation
Title: Fire Monitoring Handbook plots
Type: Monitoring Protocol
Date:

1.0 Background, Justification, and Objectives

Fire is a major mechanism of change on the Kenai National Wildlife Refuge (KNWR or Refuge). The use of fire is one of the most powerful manipulative tools available to managers of the Refuge. Two objectives of the Refuge's Fire Management Plan (KNWR Fire Management Team, 2001) are to

- reduce the threat of unwanted wildland fire in the wildland-urban interface, in high-use recreation areas and in critical habitats, through mechanical hazard fuel reduction and fire use projects; and
- utilize wildland and prescribed fire as a cost-effective habitat management tool to maintain or enhance the natural diversity of ecosystems, wildlife habitats and wilderness values, and to maintain existing populations of moose and other early seral-dependent species.

In order to measure the effects of fire on fuel loading and vegetation on the Refuge, KNWR staff established and sampled 71 plots using the USDI National Park Service's Fire Monitoring Handbook (FMH) protocols (USDI National Park Service, 1992).

2.0 Management Action Thresholds

In the Mystery Creek controlled burn units, a primary management objective was reduction of hazard fuels, specifically a removal of 90% of black spruce. A secondary objective was to increase the abundance of browse species.

3.0 Sampling Design

The populations sampled were seven study areas: three groups of burn units where controlled burns were planned and four areas recently burned by wildfires (Figure 1).

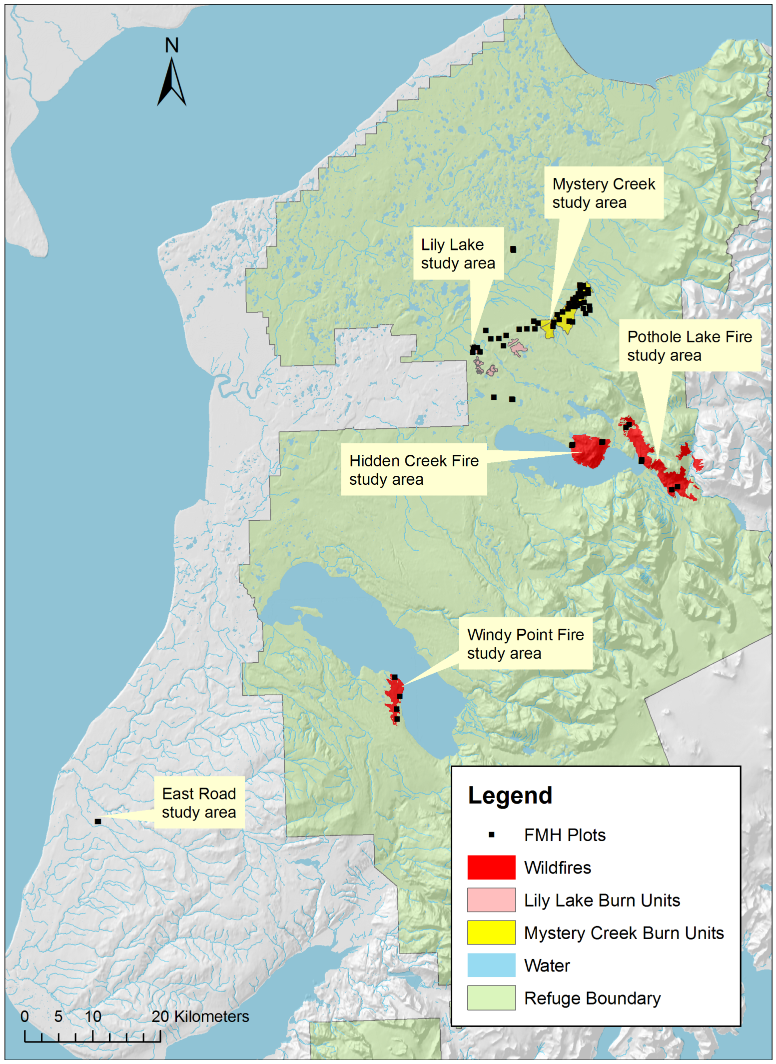

Figure 1. Study Areas.

Mystery Creek study area

The Mystery Creek study area was located at the intersection of Mystery Creek Road with the natural gas pipeline at 60.63º N, 150.30º W (Figure 2). The entire area had been burned by the stand-replacing1947 fire. Continuous stands of 50-year-old black spruce (*Picea mariana*) dominated, with a few older quaking aspen (*Populus tremuloides*) towering over the low spruce canopy. White spruce (*Picea glauca*) and paper birch (*Betula papyrifera*) were also present within the study area.

Forty-two plots were installed in the Mystery Creek study area from 1994 to 1996.

A prescribed fire was started by USFWS personnel on June 22, 2002. Flaming fronts and smoldering fire burned much of unit 5 on June 22 and unit 6 between July 1 and July 3. On the days while most of the burning was taking place, humidity ranged from 39 to 53%, average temperatures ranged from 64 to 71° F, and average wind speed ranged from 1 to 5 mph (Olson, *et al.*, 2003).

Twelve of the 42 FMH plots were burned. When the area was surveyed in 2004, it was characterized by blackened, partially burned duff, little brush, and blackened, standing black spruce poles. One of the 12 burned plots could not be located in 2004, so only 11 plots were sampled.

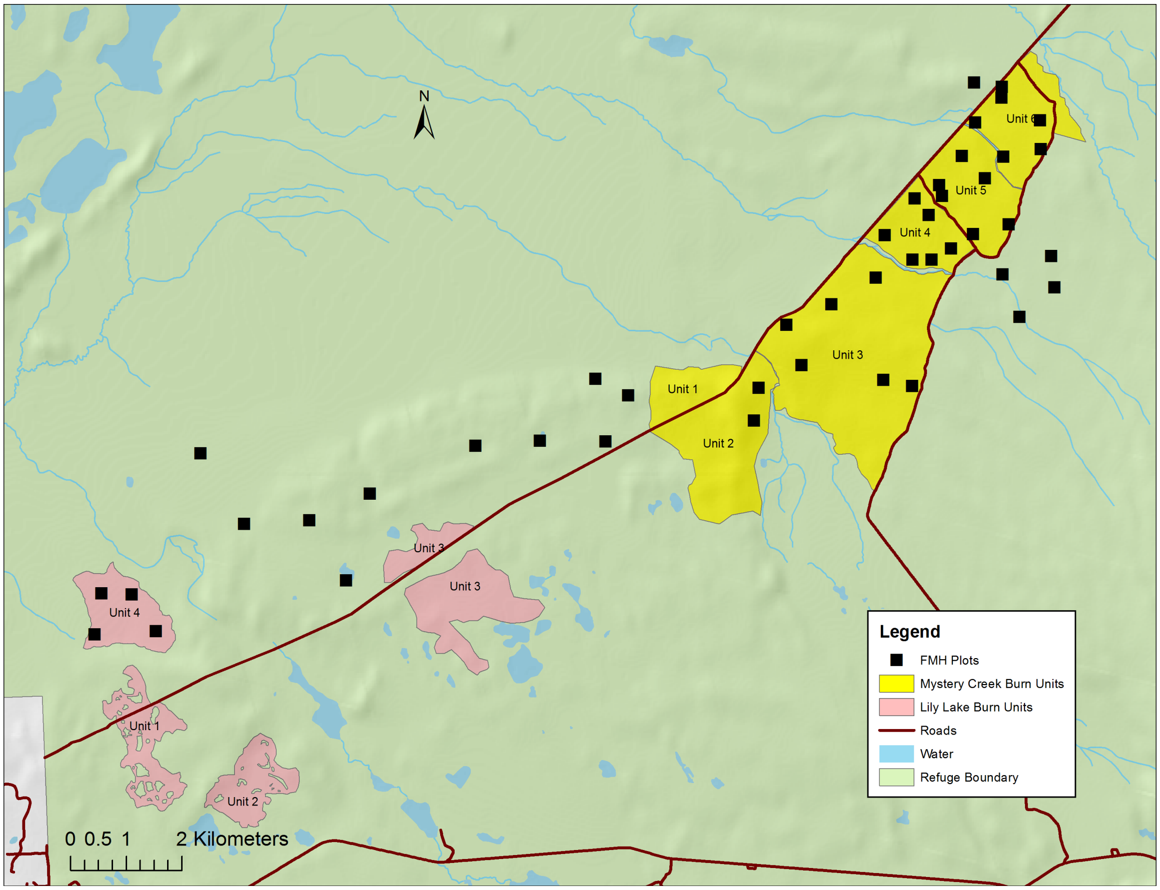

Figure 2. Mystery Creek and Lily Lake burn units.

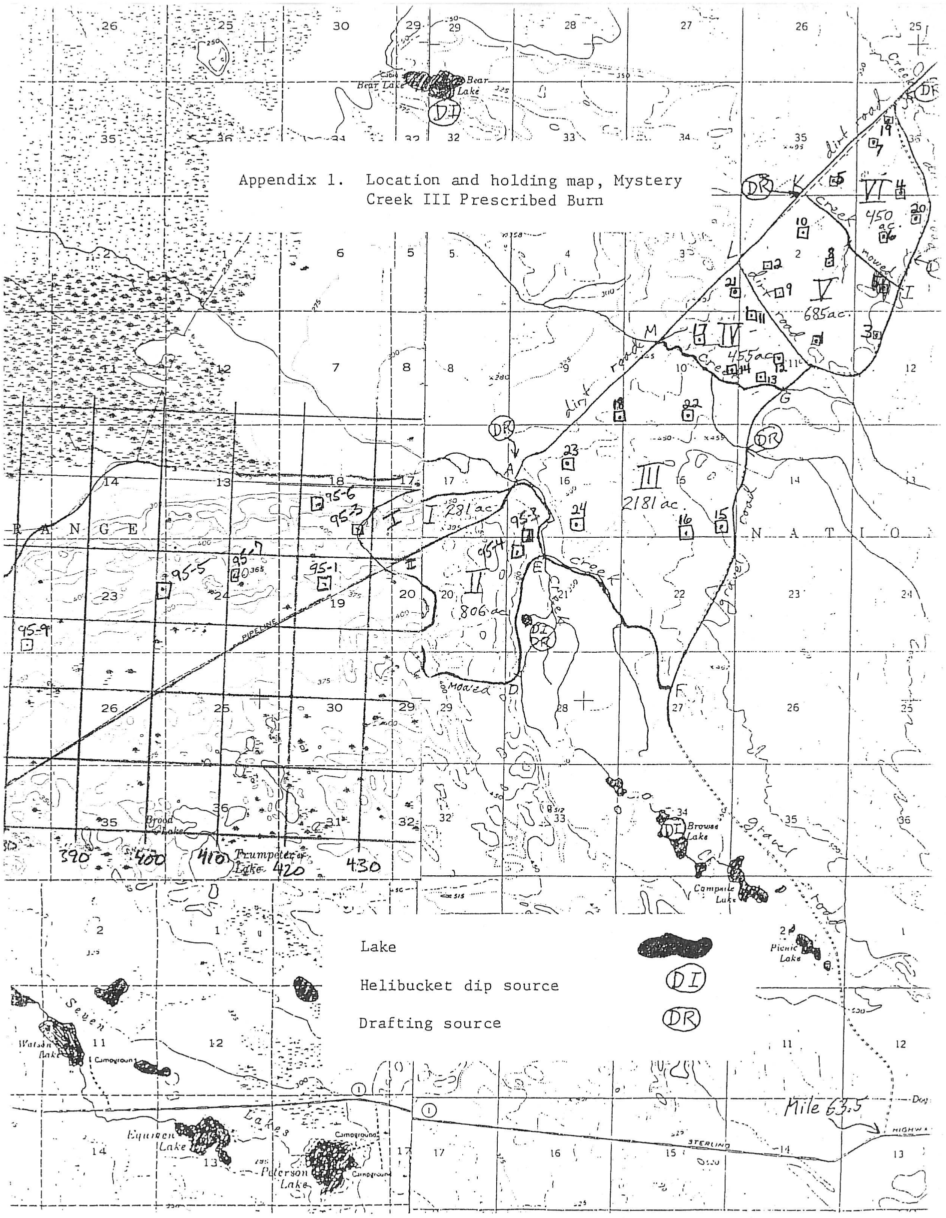

Figure 3. Map of Mystery Creek FMH plots dated 1995.

Lily Lake study area

Four plots were established in 1998 inside Lily Lake controlled burn unit 4 (Figure 2). This area had received a mechanical crushing treatment in preparation for burning. The area has not been burned.

East Road study area

Two plots were installed and sampled in 2001 off of East Road east of Happy Valley (59.965º N, 151.603º W). This area has not burned.

Moose Exclosures study area

Nine plots were established and sampled inside and outside of moose exclosures between 1994 and 1995. Exclosures were fenced areas designed to exclude moose and were located off of Skilak Lake Loop Road and at the Moose Research Center at the end of Swan Lake Road. FMH plots had been sampled inside and outside the exclosures to measure the effect of browsing by moose on vegetation. GPS coordinates were not recorded for most of these plots.

Windy Point Fire study area

The Windy Point study area was located within the Windy Point burn on the southern shore of Tustumena Lake at 60.12º N, 150.81º W (Figure 4).

An escaped campfire started the Windy Point fire on August 30, 1994. The fire burned slowly in the duff, eventually consuming 1,047 ha of black spruce forest and mixed white spruce/hardwood forest by the time the fire was considered to be out around September 30. This late-season fire had a long residence time, completely consuming the litter and duff layers in much of the burn area. When the four FMH plots were established, the area was characterized by standing snags and downed slash over mineral soil with high densities of new birch seedlings.

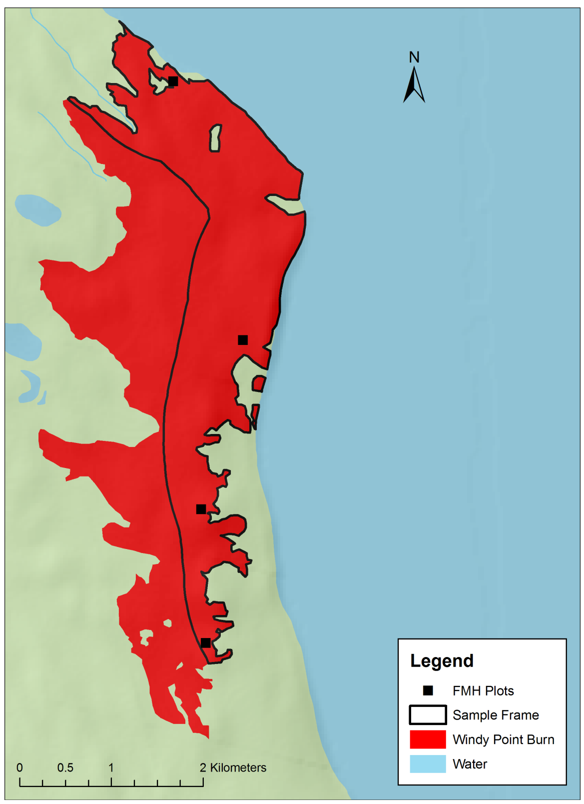

Figure 4. Windy Point Fire.

Pothole Lake Fire study area

The Pothole Lake Fire burned 3,475 ha in 1991. Six plots were installed and sampled in 1994 in three areas accessible by road or float plane. These plots have not been revisited.

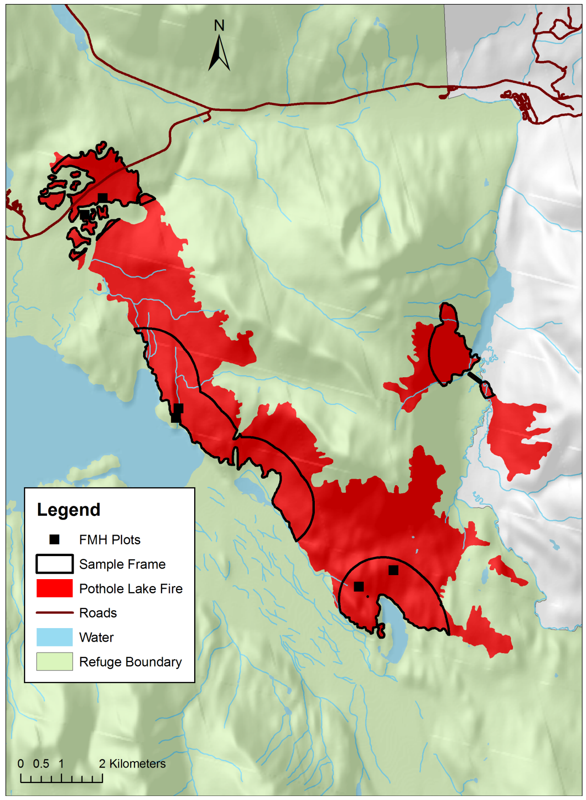

Figure 5. Pothole Lake Fire.

Hidden Creek Fire study area

The Hidden Creek Fire burned 2,079 ha in 1996. Four road-accessible plots were established and sampled in 1997. These plots have not been revisited.

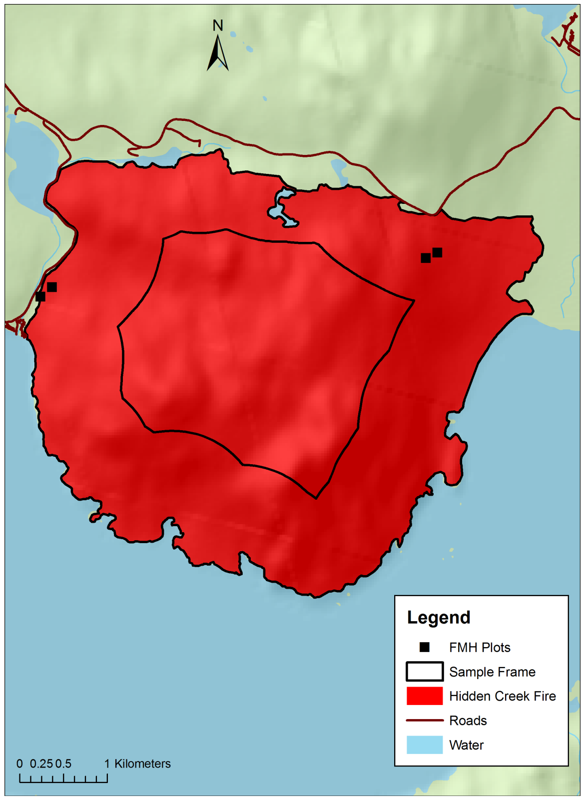

Figure 6. Hidden Creek Fire.

3.1 Target Frame

For each study area, the sample population would be a set of 50 m × 20 m plots completely covering the study area. Since each plot was randomly placed with its major axis at a random azimuth, the plots would not form a tessellating pattern.

3.1.A Spatial dimension

The spatial extent of the target frame is an entire burn unit, set of burn units, or area burned by a wildfire.

3.1.B Temporal dimension

Metrics represented a single growing season, e.g., the mass per unit area of woody fuels 1-3 in. in diameter in the Windy Point Burn in 2004.

3.2 Sample Frame

3.2.A Spatial dimension

For the controlled burn units, the target frame and the sample frame were the same because the entirety of the burn units were accessible and the distribution of plots was representative of these areas.

For the wildfires, the sample frame was that portion of the target frame that could be reached with reasonable effort, generally within about 1 km walking distance from points accessible by truck, boat, or float plane.

3.2.B Temporal dimension

The temporal dimension of the sample frame was the same as the temporal dimension of the target frame.

3.2.C Sample unit.

Spatial dimension:

The sample units were 50 m × 20 m, rectangular plots, each plot with its major axis oriented at a random azimuth.

Temporal dimension:

One plot was surveyed per day and each plot was surveyed once in a growing season. Since only one plot could be surveyed per day, the survey dates for all plots sampled were staggered. A single survey of a plot was considered to be representative of that plot for a growing season.

3.2.D Sample observations

The measurements below were observed at each plot.

- mass per unit area (tons/acre) of woody fuels 0 - ¼ in. diameter (1 hr. fuels)
- mass per unit area (tons/acre) of woody fuels ¼ in. - 1 in. diameter (10 hr. fuels)
- mass per unit area (tons/acre) of woody fuels 1 in. - 3 in. diameter (100 hr. fuels)
- mass per unit area (tons/acre) of live woody fuels > 3 in. diameter (1000 hr. fuels)
- mass per unit area (tons/acre) of dead woody fuels > 3 in. diameter (1000 hr. fuels)
- mass per unit area (tons/acre) of litter
- mass per unit area (tons/acre) of duff
- brush density (individuals/m^2) for each shrub species
- herbaceous density (% cover) for each herbaceous species
- herbaceous density (point-intercept density) for each herbaceous species
- seedling tree density (individuals/m^2) for each tree species
- seedling tree heights (categorical) for each tree species
- pole-size tree density (individuals/m^2) for each tree species
- pole-size tree heights (categorical) for each tree species
- pole-size tree diameter at breast height (DBH) (cm) for each tree species
- burn severity of vegetation (categorical)
- burn severity of litter and duff (categorical)

3.2.E Does the Sample Frame equal the Target Frame?

For the controlled burn units, the sample frame equaled the target frame. For the wildfire study areas, the sample frame was smaller than the target frame, including only the area that could be easily accessed in a day (Table 1). This was generally the portion of the burned area within about 1 km of roads and water bodies accessible by truck, boat, or float plane (Figures 4-6).

No actions have been undertaken to assess bias from frame mismatch.

Table 1. Comparison of Target Frames and Sample Frames for the Wildfires.

Study Area	Target Frame Area (ha)	Sample Frame Area (ha)	Sample Frame Area : Target Frame Area
Pothole Lake Fire	3475	1236	0.36
Hidden Creek Fire	2079	1414	0.68
Windy Point Fire	1047	550	0.53

3.3 Sample Selection Design

Samples were selected by judgment sampling. Plot locations were chosen to be broadly distributed over the sample frames and to be representative of the target frames.

Mystery Creek study area

The 42 Mystery Creek plots were installed and surveyed pre-fire over a three-year period from 1994 to 1996 within and near burn units where prescribed burns were planned (Figure 2). Plot locations were selected randomly with a constraint that none were to be adjacent to roads. All of the plots were installed in black spruce forest. Twelve of the plots established in 1994 were burned in the 2002 Mystery Creek prescribed burn. In 2004, one of these plots was not found, but the remaining 11 were resurveyed post-fire.

Windy Point study area

Four representative sites were chosen within the 1994 Windy Point Burn (Figure 4). Two of these plots were placed in mixed White Spruce and Paper Birch forest; two were placed in Black Spruce forest. These plots were sampled post-fire in 1997, 1999, and 2004.

3.4 Measurement Selection

3.4.A Response measurement scale

Table 2. Measurement scales.

Metric	Measurement scale
mass per unit area of fuels	continuous
densities	continuous
tree heights	summary of nominal measurements (height classes)
tree diameter	continuous
burn severity	summary of nominal measurements

3.4.B Measurement Methods

See section 5.0.

3.4.C Bias

Selection of plots by judgment sampling and misalignment of the sample frame with the target frame were probably the largest sources of potential bias, although plots were selected to be representative of the burned areas. The point-intercept methods used were difficult to apply consistently and may have led to some observer-dependent bias. Detection rates for the plant species of interest were assumed to be quite high, a reasonable assumption in this case because the species of interest were conspicuous and easily identified. Although spatial independence was not investigated statistically, plots were intentionally spaced widely to be as independent as possible.

3.5 Estimation / Analysis

3.5.A Summary Statistic of interest

The summary statistics of interest were the mass per unit area of several categories of fuels and the densities of various categories of plants over the study areas.

3.5.B Estimators

For all statistics that were analyzed, a measurement was obtained for each plot, e.g., the tons per acre of duff on a plot or the mean % cover of an herbaceous plant species on a plot. The means of these measurements were the summary statistics of interest.

3.5.C Standard Error Estimators for summary statistics of interest

The usual standard error estimator was used, i.e.,

$$S.E. = \frac{s}{\sqrt{n}}$$

where s is the sample standard error and n is the number of samples.

3.5.D Confidence Interval estimation methods

95% confidence intervals were computed in the usual way, i.e.,

$$\bar{x} \pm S.E. \times 1.96$$

where $\bar{x}$ is the mean.

3.5.E Recommended software

The FMH.EXE software (Sydoriak, 2001) is the preferred software for data management and analysis of FMH data. The KNWR FMH plot data currently reside in an FMH.EXE database.

FMH.EXE cannot accommodate the varying fuel transect lengths and plot sizes that were sometimes used on KNWR FMH plots, so in many cases the data must be extracted and analyzed using alternative software. FMH.EXE stores data in dBase tables, which can easily be imported into other software. The formulas for computing fuel loads are straightforward and can be implemented in various software (e.g., Microsoft Access, Microsoft Excel, or R).

3.5.F Illustration of use

An illustration of use is not provided.

3.6 Power Analysis (Required Precision)

No power analysis was performed.

3.6.A Define Statistic of interest

See section 3.5.A.

3.6.B Desired required precision or standard error magnitude

A required level of precision was not defined for KNWR FMH work, but the FMH protocols required that the standard error of all estimators should be no greater than 0.25 times the magnitude of the estimator (USDI National Park Service, 1992), i.e., the coefficient of variation should be no greater than 0.25.

3.6.C Formulas / methods for calculating sample size for a given precision.

The FMH protocols (USDI National Park Service, 1992) described methods for calculating a minimum sample size, but this was not done for the KNWR FMH program.

3.6.D Minimum sample size

A minimum sample size was not calculated.

3.7 Other Considerations

4.0 Monitoring Design

4.1 Membership Design

4.1.A Define number of panels

There was only one panel per study area.

4.1.B Define design for selecting sampling units for each panel.

For each study area, all sampling units (plots) were included in the same panel.

4.2 Revisitation Design

4.2.A How frequently is sampling conducted?

In the burn units, all plots were surveyed before burning. Burned plots were then re-surveyed two years after fire. Within areas burned by wildfires, plots were initially surveyed 1-3 years post fire. In the Windy Point Fire, plots were resurveyed 10 years post fire. No future sampling is planned.

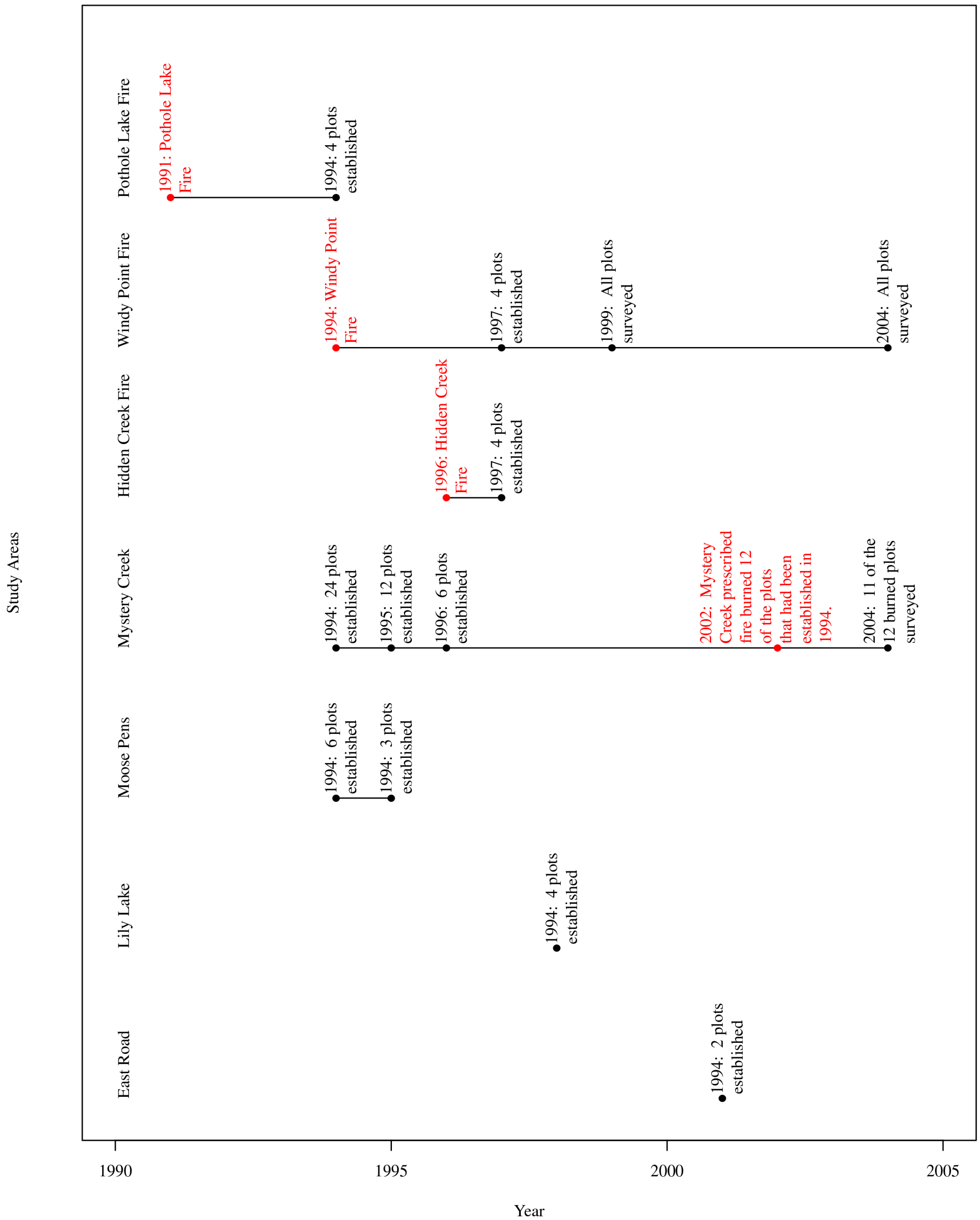

Figure 7. Timeline.

4.2.B Which panels are sampled at which times?

See section 4.2.A.

4.3 Estimation / Analysis

4.3.A Summary Statistic of interest.

See section 3.5.A.

4.3.B Estimators

See section 3.5.B.

4.3.C Standard Error Estimators for summary statistics of interest

See section 3.5.D.

4.3.D Confidence Interval estimation methods

See section 3.5.D.

4.3.E Recommended software

See section 3.5.E.

4.3.F Illustration of use

See section 3.5.F.

4.4 Power Analysis (Trend Detection)

4.4.A Define change statistic

The change statistics were the change in means (difference) between times when the study areas were surveyed.

4.4.B Define desired change magnitude to detect

The desired detectable magnitude of change was not defined.

4.4.C Define desired alpha-level for detecting the change (e.g., $\alpha < 0.20$)

A desired alpha level was not defined, but FMH protocols suggested an alpha level of 0.05 (USDI National Park Service, 1992).

4.4.D Define power required

Desired power was not defined.

4.4.E Formulas / Method for estimating power/required sample sizes/effort

A power analysis for change detection was not performed.

4.4.F Minimum Sample Size

Minimum sample sizes were not defined.

4.5 Other Considerations

5.0 Data Acquisition, Analysis, and Management

Plot layout

The 50 m × 20 m plots were laid out and staked according to the FMH handbook methods (USDI National Park Service, 1992). The origin (center) of each plot was marked with a 6 ft. metal fence post. A 50 m tape was strung at a random azimuth with the origin at 25 m. Two additional 50 m tapes were laid 10 m to each side of the center line and parallel to it. This 50 m × 20 m rectangle was made square by triangulation, using more tapes to make 3:4:5 right triangles. From 10 m, 20 m, 30 m, and 40 m along the 0P to 50P line, 50 ft. fuel transects were measured out at random azimuths. The origin (O), corners (Q1, Q2, Q3, Q4), and the midpoints of the sides (0P, 50P, P1, P2) were staked with 0.5 in. diameter, 2 ft. long, rebar stakes. The ends of the fuel transects (1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B) were staked with 0.25 in. diameter, 1 ft. long steel rods. All stakes were labeled with aluminum tags as in Figure 8.

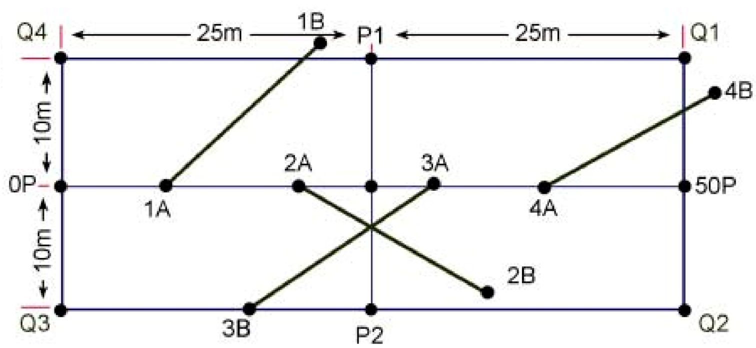

Figure 8. Plot layout.

GPS location, descriptive directions, known fire history, and plot center line azimuth were recorded when the plots were installed. In the Mystery Creek area, tagged 6 ft. metal fence posts were installed as reference stakes along access roads. The bearing and distance from the reference stake to the plot were recorded.

Finding the older plots can be difficult. When the older plots were established from 1994 to 1996, GPS units were often not available to the field crews, so coordinates were taken from topographic maps. Mistakes were sometimes made in reading the coordinates from the map. Sometimes coordinates were omitted. Fortunately, the hand-written directions and maps are generally quite good, so the plots can usually be found using the directions given on the original data sheets. In some cases, though, the landmarks used in 1994 (e.g., reference stakes on roads) could not be found ten years later. For the Mystery Creek Area, the hand-annotated topographic map (Figure 3) is useful for correctly locating the plots. A list of all plots including their estimated coordinates is included below in Table 8.

Table 3. Plot locations

Plot	Longitude	Latitude
95-1	-150.4019	60.5976
95-10	-150.4999	60.5868
95-11	-150.5212	60.5865
95-12	-150.5347	60.5982
95-2	-150.3511	60.6053
95-3	-150.3938	60.6049
95-4	-150.3531	60.6000
95-5	-150.4446	60.5977
95-6	-150.4044	60.6078
95-7	-150.4234	60.5981
95-8	-150.4886	60.5769
95-9	-150.4797	60.5907
C1-96	-150.2696	60.6219
C2-96	-150.2764	60.6530
C3-96	-150.2534	60.6245
C4-96	-150.2529	60.6195
C5-96	-150.2647	60.6150
ER1	-151.6049	59.9645
ER2	-151.6029	59.9647
HC1	-150.3161	60.4421
HC2	-150.3136	60.4430
HC3	-150.2333	60.4449
HC4	-150.2357	60.4444
I1	-150.4711	60.5063
I2	-150.5196	60.5096
I3	-150.4530	60.7038
LL1	-150.5716	60.5696
LL2	-150.5688	60.5762
LL3	-150.5590	60.5759
LL4	-150.5514	60.5698
MC1	-150.2788	60.6286
MC10	-150.2814	60.6413
MC11	-150.2930	60.6320
MC12	-150.2862	60.6264
MC13	-150.2927	60.6248
MC14	-150.2989	60.6249
MC15	-150.3008	60.6045
MC16	-150.3101	60.6057
MC17	-150.3077	60.6290
MC18	-150.3262	60.6183
MC19	-150.2673	60.6522
MC2	-150.2892	60.6367
MC20	-150.2554	60.6418
MC21	-150.2974	60.6348
MC22	-150.3112	60.6222

MC23	-150.3411	60.6152
MC24	-150.3367	60.6086
MC3	-150.2669	60.6299
MC4	-150.2552	60.6465
MC5	-150.2765	60.6466
MC6	-150.2677	60.6409
MC7	-150.2675	60.6504
MC8	-150.2741	60.6375
MC9	-150.2884	60.6350
MP4	-150.4516	60.7026
O1	-150.4692	60.5056
O3	-150.4530	60.7045
PHLF1	-150.1693	60.4626
PHLF2	-150.1611	60.4662
PHLF3	-150.0388	60.3813
PHLF4	-150.0546	60.3780
PHLF5	-150.1326	60.4170
PHLF6	-150.1314	60.4190
WPB1	-150.8072	60.0895
WPB2	-150.7979	60.1190
WPB3	-150.8072	60.1026
WPB4	-150.8099	60.1445

Sampling of fuels

Fuels were inventoried along four 50 ft. transects using the methods of Brown (1974) as described in the FMH handbook. From the A stake of each transect (e.g., 1A), a 50 ft. long, 1 cm wide tape was stretched to the corresponding B stake (e.g., 1B) so that 0 ft. was at A and 50 ft. was at B. Table 4 lists the standard transect lengths for which each size class of woody fuel that was tallied. Sometimes different transect lengths were used (e.g., the transect length for 0-1/4 in. woody fuels was reduced to 6 ft. on the Windy Point Burn plots). For transect lengths less than 50 ft., the transect began at 0 ft. (e.g., a 12 ft. transect started at the A stake and proceeded to 12 ft. along the tape). Slope of the fuels transect (from the A to the B stake) was recorded.

Along each transect, every particle of downed woody material intercepted along the right side of the tape (the right side proceeding from 0 ft. to 50 ft.) from the ground up to 6 ft. above the ground was tallied for each size class. A particle or branch was tallied on the basis of whether its imaginary longitudinal, possibly curved center line crossed the tape. Intercepts of parts of standing trees were ignored. Cones, bark, and leaves were not counted. When multiple branches or twigs of a limb were intercepted, each intercept was tallied. Particles buried more than halfway into the duff at the point of intersection with the tape were ignored. Diameters of logs over 3 in. and whether or not they were sound or rotten were recorded.

Table 4.Transect lengths for the fuel diameter classes

Fuel diameter (in.)	Transect length (ft.)
0–0.25	12
0.25–1	12
1–3	12
3	50

Litter and duff depth measurements were taken at 1 ft., 5 ft., 10 ft., 15 ft., 20 ft., 25 ft., 30 ft., 35 ft., 40 ft., and 45 ft. along each 50 ft. fuel transect. Measurements were made from the surface of the litter using a ruler graduated in 0.1 in. increments. Litter was defined as all non-woody plant material on the forest floor excluding living vascular plants. Living and dead mosses and lichens were included in this layer. The duff layer was defined as organic matter at various stages of decomposition between the litter layer and mineral soil.

For post-burn plots, burn severity was rated according to the FMH protocols.

Vegetation Sampling

Consistent with the 1992 FMH protocols, four-letter codes were used to represent all species identified (Table 5).

Table 5. Species Codes.

Latin Name	Common Name	Code
Achillea borealis	Yarrow	ACBO1
Actaea rubra	Baneberry	ACRU1
Arctostaphylos uva-ursi	Bearberry	ARUV1
Betula nana	Dwarf Birch	BENA1
Betula papyrifera	Paper Birch	BEPA1
Corydalis sempervirens	Rock Harlequin	COSE1
Echinopanax horridum	Devil's Club	ECHO1
Empetrum nigrum	Crowberry	EMNI1
Epilobium angustifolia	Fireweed	EPAN1
Epilobium latifolia	River Beauty	EPLA1
Equisetum arvens	Field Horsetail	EQAR1
Equisetum pratense	Meadow Horsetail	EQPR1
Equisetum scirpoides	Dwarf Scouringrush	EQSC1
Equisetum sylvaticum	Woodland Horsetail	EQSY1
Equisetum spp	Horsetail species	EQUI1
Galium boreale	Northern Bedstraw	GABO1
Galium triflorum	Sweet-Scented Bedstraw	GATR1
Geranium erianthum	Wild Geranium	GEER1
Geocaulon lividum	False Toadflax	GELI1
Poaceae	total grasses	GRAS1
Gymnocarpium dryopteris	Oak Fern	GYDR1
Ledum palustre	Labrador Tea	LEPA1
Linnaea borealis	Twin Flower	LIBO1
Listera cordata	Heartleaf Twayblade	LICO1
Lupinus nootkensis	Nootka Lupine	LUNO1
Lycopodium annotinum	Stiff Clubmoss	LYAN1
Lycopodium clavatum	Running Clubmoss	LYCL1
Lycopodium complanatum	Creeping Jenny	LYCO2
Moehringia lateriflora	Bluntleaf Sandwort	MOLA1
Oxycoccus microcarpus	Small Cranberry	OXMI1
Picea Glauca	White Spruce	PIGL1
Picea Mariana	Black Spruce	PIMA1

Picea spp.	Spruce species	PISP1
Polemonium acutiflorum	Tall Jacob's Ladder	POAC1
Populus balsamifera	Cottonwood	POBA1
Populus tremuloides	Quaking Aspen	POTR1
Pyrola asarifolia	Liverleaf Wintergreen	PYAS1
Pyrola grandiflora	Large-flowered Wintergreen	PYGR1
Pyrola secunda	Sidebells Wintergreen	PYSE1
Ribes spp.	Currant spp.	RIBE1
Ribes glandulosum	Skunk Currant	RIGL1
Ribes hudsonianum	Northern Black Currant	RIHU1
Rosa acicularis	Prickly Rose	ROAC1
Rubus spp.	Bramble spp.	RUBU1
Rubus chamaemorus	Cloudberry	RUCH1
Rubus pedatus	Trailing Raspberry	RUPE1
Sambucus racemosa	Elderberry	SARA1
Salix spp	total willows	SASP1
Sorbus sitchensis	Sitka Mountain Ash	SOSI1
Spiraea beauverdiana	Alaska Spirea	SPBE1
Streptococcus amplexifolius	Clasp leaf Twisted stalk	STAM1
Trientalis europaea	Starflower	TREU1
Vaccinium spp.	Vaccinium species	VACC1
Vaccinium uliginosum	Bog Blueberry	VAUL1
Vaccinium vitis-idaea	Lingonberry	VAVI1
Viburnum edule	Squashberry	VIED1

Seedling trees, defined by a DBH < 2.5 cm, within a 10 m × 5 m rectangle (described by the points O, P1, 30 m on the Q4-Q1 tape, and 30 m on the 0P-50P tape) were tallied by species. When seedling trees were dense (≥ 50 individuals per 50 m^2), the sampling area was reduced to a rectangle 2.5 m × 5 m (described by the points O, 5 m on the P1-P2 tape, and 27.5 m on the 0P-50P tape). Because of extremely high seedling densities, 1 m^2 and 2 m^2 plots were used on some of the Windy Point Burn plots.

Two 1 m × 50 m shrub density transects were placed along the outside of the plot along the outside of the Q4-Q1 tape and the Q3-Q2 tape. The number of shrubs within the transects was tallied by species. Only shrubs with more than half of their bases within the transect were counted. Lingonberry (*Vaccinium vitis-idaeus*) was ignored because individuals were difficult to define.

The densities of herbs and ground cover were estimated using a 50 m point intercept transect and ten 1 m^2 quadrats. The 50 m transect stretched from 0 m at the Q4 stake to 50 m at the Q1 stake. Beginning at 30 cm (not 0 cm) and at 30 cm intervals thereafter, a 6 mm × 25 mm × 1 m meter stick was held plumb (vertical), touching the ground next to the tape (the side to the outside of the plot, the left side proceeding from Q4 to Q1). At each point, every species on the ground with in a circular area roughly 4 cm in diameter was recorded as well as every plant species that touched the meter stick above the ground. Each species that touched the meter stick was scored exactly once, even if multiple individuals or multiple parts of one individual touched the meter stick more than once. Dead plant parts (e.g., dead grass blades) were not counted. Foliage or branches intercepted from trees over 2 m tall were not counted.

Herbaceous density was also estimated by cover estimates within ten 1 m^2 quadrats at 9-10 m, 19-20 m, 29-30 m, 39-40 m, and 49-50 m along the inside of the Q4-Q1 and Q3-Q2 tapes (Figure 9.). At each 1 m^2 area, a 1 m^2 frame made of PVC tubing was set on the ground and ocular estimates were made of the percent cover of every species and substrate within the square.

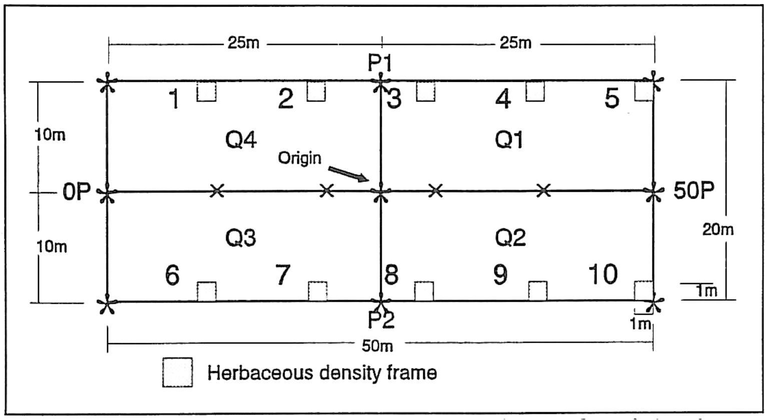

Figure 9. Locations of herbaceous density frames.

A set of eight standard index photographs was taken each time a plot was sampled. For each photograph, one person stood in the photograph holding up a paper sign marked with the plot name, the date, and the photograph code.

Table 6. Index photographs and codes.

Field of View	Code
From the 0P stake toward the plot center	0P
From stake Q4 toward stake Q1	Q4-Q1
From stake P1 toward the plot center	P1
From stake Q1 toward stake Q4	Q1-Q4
From the 50P stake toward the plot center	50P
From stake Q2 toward stake Q3	Q2-Q3
From stake P2 toward the plot center	P2
From stake Q3 toward stake Q2	Q3-Q4

Figure 10. Example of a plot index photograph.

Data Sheets

The standard data sheets provided in the FMH protocol were used. See the original data sheets for examples of use.

Data Entry

Data were entered into an FMH.EXE database.

Data Analysis

For the statistics of interest, e.g., the density of willows, A mean value was calculated for each plot, then the mean and standard deviation of all the plot values were calculated.

Fuel Loading Calculations

Fuel loads were calculated for each plot and sampling date using the methods of Brown (1974) and USDI National Park Service (1992). For each fuel transect, *slopecorr*, the slope correction factor, was calculated using the formula

$$slopecorr_t = \sqrt{1 + [(slope_t)(0.01)]^2}$$

where t = index for transects and *slope* = % slope of the transect. For woody fuels up to 3 in. in diameter, *obscorr*, fuel particle observations corrected for slope, was calculated for each plot using the formula

$$obscorr = \sum_{t=1}^{n} (obs_t)(slopecorr_t)$$

where n = number of transects, t = index for transects, and *obs* = fuel particle count for the transect. For woody fuels up to 3 in. in diameter, *ta*, tons per acre, was calculated for each plot using formula

$$ta = \frac{(11.64)(obscorr)(w_d)(w_s)(w_a)}{tranlength}$$

where w_d = weighted average squared diameter, w_s = weighted average specific gravity, w_a = weighted average angle to horizontal, and *tranlength* = sum of the lengths of all transects measured in feet.

For woody fuels greater than 3 in. in diameter, *obscorr*, fuel particle observations corrected for slope, was calculated for each plot using the formula

$$slopecorr = \sum_{t=1}^{n} \left[\left(\sum_{i=1}^{obs} diameter_i^2 \right) (slopecorr_t) \right]$$

where n = number of transects, t = index for transects, *obs* = number of observations, i = index of observations, and *diameter* = particle diameter in inches. Tons per acre, *ta*, of woody fuels greater than 3 in. in diameter was calculated using the formula

$$ta = \frac{(11.64)(obscorr)(w_s)(w_a)}{tranlength}$$

where w_s = weighted average specific gravity, w_a = weighted average angle to horizontal, and *tranlength* = sum of the lengths of all transects in feet.

Tons per acre of litter and duff, *ta*, was calculated for each plot using the formula

$$ta = (1.815)(B)(d)$$

where B = bulk density (lb./ft.^{3}), and d = average duff/litter depth (in.) over all transects on a plot.

Fuel constants were extracted from the FMH.EXE software (Sydoriak, 2001) and from Brown (1974).

Fuel Type	w_d	w_s	w_a	B
woody, 0-0.25 in.	0.006	0.67	1.13	-
woody, 0.25-1 in.	0.24	0.65	1.13	-
woody, 1-3 in.	2.19	0.49	1.13	-
woody, 3+ in., sound	-	0.4	1	-
woody, 3+ in., rotten	-	0.3	1	-
litter	-	-	-	1.1
duff	-	-	-	7.2

Data Archival

Original paper data sheets and maps are stored in the vegetation data drawers. Photo prints are archived in the photo drawers in the specimen room attached to the lab. Digital images are archived in the biology image library on the Refuge's shared server at the file bath below.

I:\BIOLOGY\Archive\ImageLibrary\

The FMH data is stored in the biology data folder on the Refuge's shared server at the file path below. A copy of the FMH.EXE program is stored in the same folder.

I:\BIOLOGY\Data\ProjectData\FMH\

Data stored on the shared server is backed up regularly.

The FMH protocols, including templates for all data sheets, are stored as a hard copy in the file cabinet with all of the FMH data. A scanned pdf version is located at the file path below. Note that we have copies of the 2001 and 2003 FMH protocols, also, but that we followed the 1992 protocols.

I:\BIOLOGY\Active\Ecologic\fire\FMH

6.0 Personnel Requirements and Training

Sampling work required at least two biological technicians to perform sampling and then one field technician to enter data. Since no further sampling is planned, all that is required is archival of data, photographs, and data sheets.

7.0 Operational Requirements

Sampling was carried out during June and July so that plants were sampled well after green-up, but before fall senescence. One day was required to sample each plot. Trucks, boats, or float planes were used to access the plots.

8.0 Special Considerations

No permitting was performed.

9.0 Costs

No budget has been prepared.

10.0 Reporting Procedures

A report on the Mystery Creek and Windy Point study areas was prepared in 2005 (Bowser, 2005). No further reporting is planned.

11.0 Literature Cited

Bowser, M. L. 2005. Report on the Mystery Creek and Windy Point FMH plots. US Fish & Wildlife Service, Kenai National Wildlife Refuge. Soldotna, Alaska.

Brown, J. K. 1974. Handbook for inventorying downed material. USDA Forest Service, Intermountain Forest and Range Experiment Station. Ogden, Utah. General Technical Report INT-16.

KNWR Fire Management Team. 2001. Kenai National Wildlife Refuge 2001 fire management plan. U.S. Fish & Wildlife Service, Kenai National Wildlife Refuge. Soldotna, Alaska.

Olson, D., R. Ottmar, and R. Vihnanek. 2003. The 2002 Mystery Creek Burn: Preliminary forest floor consumption and fuel moisture report to the U.S. Fish and Wildlife Service. USDA Forest Service Report. Pacific Northwest Research Station, Seattle Forestry Sciences Laboratory. Seattle, Washington.

Sydoriak W. M. 2001. FMH.EXE. Version 3.1x. National Park Service. Boise, Idaho.

USDI National Park Service. 1992. Western Region Fire Monitoring Handbook. USDI National Park

Service, Western Region. San Francisco, California.

12.0 Review and Approvals

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Review Manager; Date
Approved for implementation by:
Refuge Manager; Date